# Analysis of oxygen spectral lines in the 1.27 micron band for the ASCENDS mission

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*Abstract*— **The ASCENDS mission requires simultaneous laser remote sensing of CO2 and O2 in order to convert CO2 column number densities to average column CO2 mixing ratios (XCO2). As such, the CO2 column number density and the O2 column number density will be utilized to derive the average XCO2 column. NASA Langley Research Center, working with its partners, is developing O2 lidar technology in the 1.26-1.27-µm band for surface pressure measurements. The O2 model optical depth calculation is very sensitive to knowledge of the transmitted wavelengths and to the choice of Voigt input parameters. Modeling using the HITRAN database is being carried out to establish the evolution of candidate O2 absorption lines as a function of atmospheric parameters such as altitude, temperature, and pressure. Preliminary results indicate limitations of the Voigt profile and the need to utilize more advanced models which take into account line mixing, line narrowing, and speed dependence. In this paper, we evaluate alternative lineshape models to establish the optimum lineshapes which better account for the variability of individual O2 absorption lines at various atmospheric conditions. The combination of our modeling efforts with accurate laboratory measurements is anticipated to aid in achieving the desired CO2 mixing ratio measurement accuracy requirement of for the ASCENDS mission.**

***Keywords-ASCENDS; Oxygen Lidar; CO2 Mixing ratio; HITRAN; Voight Profiles***

## I. INTRODUCTION

The National Research Council's (NRC) Decadal Survey (DS) of Earth Science and Applications from Space has identified the Active Sensing of $CO_2$ Emissions over Nights, Days, and Seasons (ASCENDS) as an important atmospheric science mission. The $CO_2$ mixing ratio needs to be measured to a precision of 0.5 percent of background or better (slightly less than 2 ppm) at 100-km horizontal resolution overland and 200-km resolution over oceans. To meet this goal, the ASCENDS mission requires simultaneous laser remote sensing of $CO_2$ and $O_2$ in order to convert $CO_2$ column number densities to average column $CO_2$ mixing ratios ($XCO_2$). As such, the $CO_2$ column number density and the $O_2$ column number density will be used to derive the average $XCO_2$ column. NASA Langley Research Center, working with its partners, is developing $CO_2$ and $O_2$ lidar technology in the 1.57-µm and 1.26-1.27-µm bands to be used for $XCO_2$ measurements.

In this paper we describe our ongoing modeling work and an improved modeling approach to enhance the accuracy of CO2 and O2 line-by-line transmission simulations. In particular, alternative lineshape models are evaluated to establish the optimum lineshapes which better account for the variability of individual absorption lines at various atmospheric conditions. In addition we are enhancing our models by incorporating new additional data such as the collision induced absorption cross-sections for the O2 molecule and updated atmospheric profile models.

## II. $CO_2$ AND $O_2$ TRANSMISSION MODELING

Our current $CO_2$ and $O_2$ transmission modeling efforts include the selection of the optimum laser wavelengths in the 1.57 and 1.26-1.27 micron bands by investigating the behavior of absorption lines in these bands as a function of altitude.

Traditional transmission simulation approach is based on the use of the HITRAN database [1] and as such has some accuracy limitations. Currently, the HITRAN database does not provide parameters required for modeling of spectral line shapes more accurate than Voigt. To achieve the accuracy set forth for the ASCENDS mission, the use of more sophisticated line shape models and consequently knowledge of additional spectral parameters unavailable in HITRAN is required. Several groups have done extensive measurements for the $CO_2$ molecule bands near 1.57 micron which provide more accurate and complete data than that currently available in the HITRAN database. For example, the recent studies by Devi et al. and Predoi-Cross et al provide additional data for line-by-line simulations such as pressure shift temperature dependence and speed dependent Voigt coefficients, as well as line-mixing parameters [2,3]. We used their results for line-by-line transmission modeling in the $CO_2$ band near 6348 $cm^{-1}$ as a replacement of the HITRAN database parameters to improve the accuracy of our $CO_2$ transmission calculations. For example, Fig 1 presents a comparison of the calculations carried out using HITRAN 2008 and the Devi & Predoi-Cross

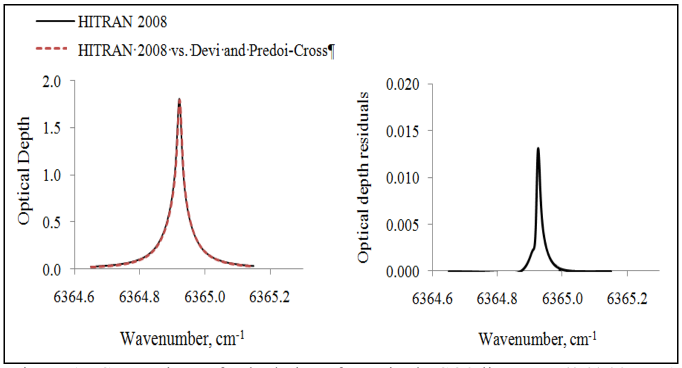


Figure 1. Comparison of calculations for a single CO2 line near 6364.92 cm-1 using the HITRAN 2008 [1] and Devi & Predoi-Cross data [2, 3].

data (Voigt profile; no speed dependence, line mixing or temperature dependence of line shifts is included). As can be seen, the differences in the spectral parameters alone result in residuals exceeding the required accuracy set forth for the ASCENDS mission measurements.

## III. Summary and Conclusions

A summary of our modeling method is presented in Fig. 2. As can be seen, we are using previously reported data for speed dependent Voigt line-by-line transmission modeling of $CO_2$ atmospheric transmission. An extension of this approach onto the $O_2$ line-by-line simulations is planned after the required spectral parameters have been determined through experiments and least squares multispectral fitting. In addition, we are looking into supplementing our $O_2$ line-by-line transmission simulations with collision induced absorption data soon to be included in the HITRAN database (from: Dennis K. Killinger, Laurence S. Rothman, private communication).

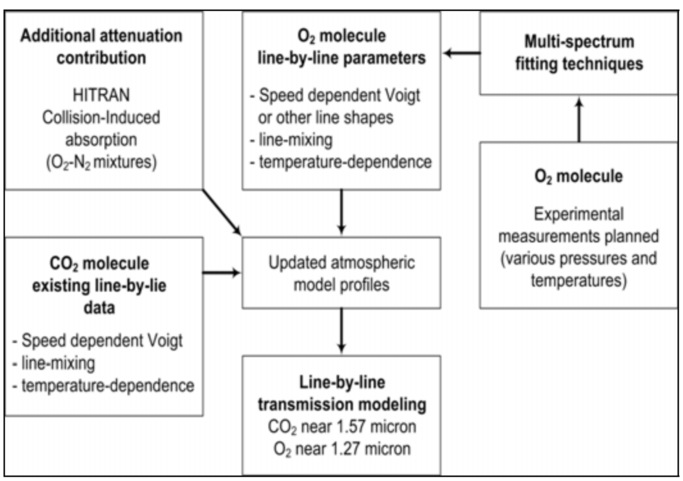


Figure 2. Summary of the modeling approach being implemented for the atmospheric transmission modeling of $CO_2$ and $O_2$.

Toward this end we have carried out preliminary simulation studies for the optimum selection of laser wavelengths for $CO_2$ and $O_2$ sensing. Our current work includes modification of our calculations by including the latest data. A speed dependent Voigt line-by-line modeling approach based on the latest data is being implemented to provide improved accuracy of $CO_2$ transmission calculations. Laboratory measurements are planned to obtain the required spectral parameters for $O_2$ line-by-line transmission calculations using more advanced lineshape models. The results of our calculations for selected $CO_2$ and $O_2$ lines at different atmospheric conditions will be presented.


## Acknowledgment

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